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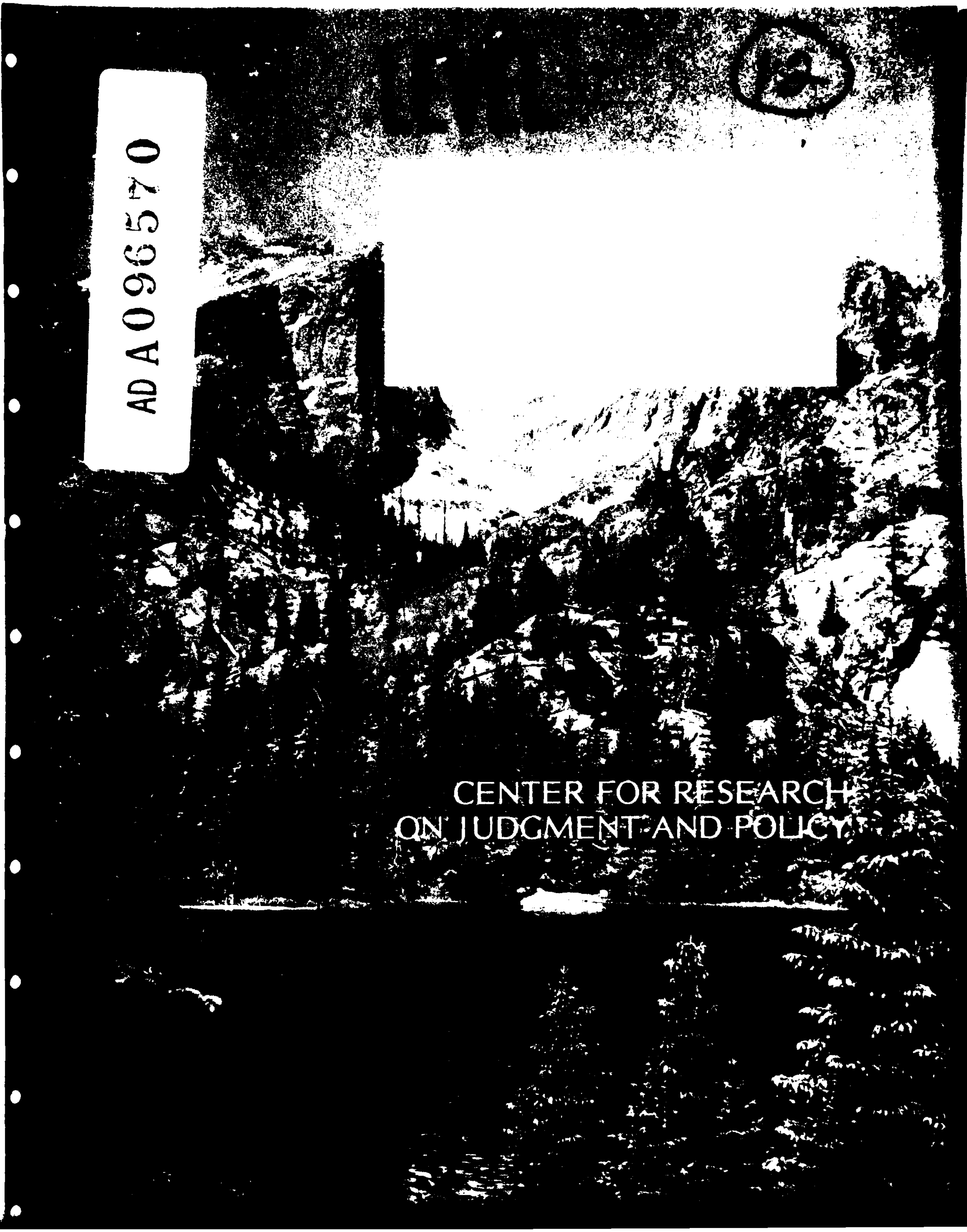
CENTER FOR RESEARCH
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IN INTUITIVE AND ANALYTICAL COGNITION

10 Kenneth R. Hammond

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UNIVERSITY OF COLORADO

INSTITUTE OF BEHAVIORAL SCIENCE

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Center for Research on Judgment and Policy

Report No. 231

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CRJP 231	2. GOVT ACCESSION NO.: AD-A096 570
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): PRINCIPLES OF ORGANIZATION IN INTUITIVE AND ANALYTICAL COGNITION	5. TYPE OF REPORT & PERIOD COVERED: Technical
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Kenneth R. Hammond	8. CONTRACT OR GRANT NUMBER(s): N00014-77-C-0336
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Center for Research on Judgment and Policy, Institute of Behavioral Science, University of Colorado, Boulder, CO 80309	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Office of Naval Research, 800 N. Quincy Street, Arlington, VA 22217	12. REPORT DATE: February 15, 1981
	13. NUMBER OF PAGES: 78
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

schema, vicarious functioning, judgment, decision making, heuristics, problem solving, intuition, analysis, quasi-rationality, bounded rationality, paramorphic models

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report continues the development of a theory of cognition (introduced in a previous report, Hammond, 1980) that is intended to unify, rather than replace, the major approaches to judgment and decision making. Concepts referring to the organization of knowledge are enlarged and differentiated in relation to intuitive, quasi-rational and analytical modes of cognition. Definitions and predictions of the occurrence of various principles of organization are provided. A new concept, the shifting locus of vicarious

20. ABSTRACT (Continued)

functioning, is also introduced and its explanatory potential is illustrated. The implications of the foregoing for unifying problem solving research and theory with that of decision research and theory are put forward.

PRINCIPLES OF ORGANIZATION
IN INTUITIVE AND ANALYTICAL COGNITION

A previous technical report (Hammond, 1980) presented a general theory of cognition that is intended to unify, rather than replace, the major approaches to judgment and decision making that are described in Hammond, McClelland, and Mumpower (1980). In that general theory (termed Cognitive Continuum Theory) a conceptual framework that describes task properties and cognitive properties, together with predictions of behavior that follow from their interaction was presented. (Tables 1, 2 & 3 of Hammond, 1980, present this conceptual framework, including predictions, and they are reproduced here; see Appendix A.) The most important concept within this framework concerns the <u>organization</u> of knowledge in judgment and decision making. No question in the history of the study of cognition has been more salient or pervasive than the question of the nature of principle(s) by which knowledge, or information, is organized prior to the exercise of a judgment, the production of an answer to a problem, or any other outcome of cognitive activity.

A second topic addressed in the previous report is equally salient and pervasive in the history of the study of cognition; it concerns the nature of, and relation between, <u>intuitive and analytical modes of cognition</u>. The contrast between these two modes of cognition is implicit in virtually all studies of judgment and decision making, as well as problem solving, despite the fact that neither mode of cognition has been securely anchored in theory or in research techniques.

The present report addresses both topics in greater detail than was possible in the previous report (Hammond, 1980), and brings them in relation to one another in the context of the Cognitive Continuum Theory. In what follows, definitions of what is meant by intuitive organizing principles, analytical organizing principles and quasi-rational organizing principles are presented. Predictions are then made with regard to the specific forms such principles take in intuition-inducing tasks, the (in-between) tasks that induce quasi-rationality, and analysis-inducing tasks. The theoretical basis for these predictions is intended to further the unification of theory and research in judgment and decision making, as well as extending the unifying effort to include theory and research in problem solving. Special emphasis is placed upon the unifying potential of the concept of vicarious functioning (mutual substitutability of cues and mutual substitutability of responses). In particular, the heretofore unrecognized shift in locus of vicarious functioning from the proximal/peripheral region to the central region of the organism as cognition is induced by task properties to move from intuition through quasi-rationality to analysis (and vice versa) offers new opportunities for unifying what are now apparently disparate conceptual approaches to cognition.

Definitions of Principles of Organization

The Approach to Definition

Present approaches to the use of principles of organization remain satisfied with a degree of looseness and abstraction that have not materially changed during the 20th century. Pitz and Harren (1980), for example, cite Schank and Abelson's (1977) use of the enduring concept of "schemata," thus: "They suggest that understanding information is based on 'schemata,' abstract structures that provide an organization for a person's knowledge. New information is given meaning by finding a suitable schema into which it can be incorporated. Elements of the information are filled in, all under the guidance of the general structure of the schema" (p. 330). Such descriptions are satisfying because of their common sense appeal, and their ad hoc utility; but they do not help us to form conceptions of organizing principles that can be tested.

In the present approach, descriptions of the principles of organization will be required to meet three formal criteria; such descriptions will be expected to demonstrate, for example, that a putative organizing principle is (a) functionally compatible with the task properties that are predicted to induce that principle, (b) conceptually compatible with other properties of the cognate mode of cognition, and (c) functionally effective in the task situations that are predicted to induce that principle. The application of these criteria to the definition of different types of organizing principles follows.

Intuitive Organizing Principles

These are induced by the task properties that are indicated in Table 1 (see Appendix A). Among the fifteen task properties listed, it is sufficient for our present purposes to observe that intuition-inducing tasks include (a) many (5+) (b) contemporaneously displayed cues which must somehow be (c) measured without assistance by a subject who (d) does not receive feedback and (e) has no prior familiarity or (f) expertise with regard to the judgment task.

As indicated above, whatever hypothesis, concept, or principle that is put forward to describe or explain how information is organized in tasks with the above properties must be functionally compatible with these task properties; that is, it must be capable of being readily applied in these task circumstances. An intuitive organizing principle must, for example, be readily applicable to a task that presents a large number of contemporaneously displayed cues (or dimensions); an organizing principle that demands for its operation sequential presentation, dimension by dimension, of cue data would be less functionally compatible with these conditions. The same holds for the remaining task conditions.

In general, the functional compatibility of an organizing principle with task conditions to which it is applied is a requirement that has not been given due theoretical consideration; the range of task conditions to which they are intended to apply is ordinarily ignored, with the result that organizing principles purporting to govern cognitive activity are persistently over-generalized with regard to task conditions. Indeed, as pointed out in detail in Hammond (1980) and Hammond, et al. (1980), the explanatory mechanisms that are offered could be described as being isomorphic with the task that is repeatedly studied by the same investigator. (See, for example, Larkin, McDermott, Simon, & Simon, 1980, who assert that chess, algebra and physics problems exhaust the range of cognitive tasks that need to be studied; they go so far as to suggest that these topics "are serving as the *Drosophila*, *Neurospora* and *Escherichia coli* of research on human cognitive skills" (p. 1336).

Second, an intuitive organizing principle must be conceptually compatible with the other properties of intuitive cognitive activity predicted to occur in intuition-inducing tasks. Because the task properties indicated above are predicted to induce low cognitive control over cue usage, vicarious cue utilization, and rapid data processing without awareness, the properties of an intuitive organizing principle must, therefore, be nonreportable by the subject, be capable of utilizing intersubstitutable cues, and be capable of rapid data processing, in order to be conceptually compatible with these related cognitive properties (see Table 1, Appendix A). In short, the nomological network among the predicted cognitive properties is to be explicitly examined (concepts should not be treated in isolation), and the properties found therein must be compatible with one another.

To refer to the list of cognitive properties in Table 1 (Appendix A) as a "nomological network" may seem pretentious in view of the fact that no lawful relations are indicated among them; it might have been more prudent to refer to this list as a "constellation," or perhaps no more than a "list," of cognitive properties. Imprudent and pretentious as it might appear, there is a definite need not only to be specific about which cognitive properties *are* associated with one another but also to indicate which are *not* associated; doing so directly implies a necessary, if crude, functional relationship among these properties. Moreover, the list, constellation or network in Table 1 (Appendix A) purports to be complete; revision will, therefore, have to be explicit. In thus providing an explicit, complete network of those properties that are and are not expected to be associated (conceptually compatible) with one another, I meet the requirement of confronting the relationship among all of the concepts utilized in the theory.

For example, when indicating that a task presents "many contemporaneously displayed cues which must somehow be measured without assistance by a subject who does not receive feedback and has no prior familiarity or expertise with regard to the judgment task" (see Table 1, Appendix A for other task properties inducing intuition) the constellation of cognitive properties that must be compatible with the (intuitive) organizing principle induced by these properties will include rapid data processing (the judgment will occur in less than a minute), and will be a compensating rather than a noncompensating mechanism, because the other properties listed require these properties to appear; they are conceptually compatible with them.

Of course, one may dispute the necessity for the association among these concepts argued here (and, of course, such dispute is to be encouraged); when doing so, however, the dispute should be developed on the basis of a list, constellation or network of concepts that is also conceptually compatible throughout, not merely on the basis of a difference with regard to the necessity of the presence of a single task, or cognitive, property. That is, (at least) each one of the fifteen properties indicated in Table 1 (Appendix A) should be addressed.

Third, an intuitive organizing principle must be _functionally effective_ in intuition-inducing tasks. Specifically, it must be shown to be potentially capable of organizing information from a large number (5+) of simultaneously displayed, intersubstitutable cues in a way that is _robust_; good approximations to ecologically correct criterion values must be achieved irrespective of the imprecise nature of the task conditions. Differentially weighted cue data must be organized in a manner that readily permits the addition and omission of (often partially redundant) cues _without resulting in a change in judgment_ (much as perception permits a constant judgment of, say, size despite changing retinal stimuli). That is, stability in judgment, despite variation in the amount and the content of proximal data, must be achieved with a minimum of conscious cognitive labor. Otherwise, in tasks in which the appearance of cues is irregular, and in which vicarious mediation (task redundancy) provides the major source of cognitive security, a person's judgment would be hopelessly at the mercy of momentary changes in task conditions. Therefore, an intuitive organizing principle must be one that will provide stability in judgment despite variability in information and/or information source if functional effectiveness is to be achieved in intuition-inducing tasks.

The above demands and constraints for the defining properties of an _intuitive_ organizing principle thus take into account (a) task properties, (b) the nomological network of relations with other aspects of intuitive cognitive activity, as well as (c) the demands for functional effectiveness in relation to both task conditions. The organizing principle for intuitive cognitive activity does not, therefore, receive an open-ended definition; it is not simply defined as, or implied to be, the cognitive activity that occurs if and when analytical cognition is demonstrated to be absent. Most important, the extent to which any organizing principle that is put forward as meeting the aforementioned demands and constraints can be ascertained by empirical test; explicit revision is thus possible when theoretical analysis and empirical research demonstrate the inevitable need for revision. We turn now to the demands and constraints to be placed on the defining properties of analytical organizing principles.

Analytical Organizing Principles

These are induced by task properties that include (a) a few (<5) contemporaneously displayed cues, but (b) numerous, sequentially-encountered cues that are (c) quantitatively described (or objectively apparent) among which there is no (or perfect) redundancy (see Table 1, Appendix A).

Analytical organizing principles must meet the same three formal requirements as intuitive organizing principles, although their substantive requirements will differ. In this case, functional compatibility demands that the task properties permit the application of a coherent, internally, consistent organizing principle (recall the absence of these requirements for an intuitive organizing principle). If the appropriate task conditions are not present, analysis will not occur because it cannot occur. Specifically, if adequate time and reliable, objectively measured data (or objects) are present analysis can be (but, of course may not be) applied; if these conditions are not present, it will not be. Analytical organizing principles must also be conceptually compatible with the other properties of analytical cognitive activity indicated in Table 1, Appendix A. In contrast to intuitive organizing principles, conceptual compatibility in this case will not require rapid data processing without awareness, a process often referred to in ordinary language as "leaping over" requisite analytical steps. Rather, analytical organizing principles must make provision for orderly, systematic sequences of operations, carried out with high awareness that will produce sequential cognitive change in response to change in proximal data. (Rapidity of intuitive data processing -- characteristic of intuitive cognition -- is thus exchanged for the security of analytical retraceability.) In order to be functionally effective, therefore, analytical organizing principles must fit the task precisely; changes in task conditions such as the appearance of (a) new information with regard to the parameters of a principle currently in use, or (b) conditions which require the use of a wholly different organizing principle, must be detected by the organizing principle itself if it is to be functionally effective. Such sensitivity to incongruence between task and organizing principle requires the production of exact answers by the organizing principle, and precision and certainty in outcome feedback, as well as internal consistency by both. The functional effectiveness of analytical organizing principles thus requires a capacity for the production of logically defensible solutions and ready detection of, and sharp sensitivity to, errors, that is, mismatches between the answer produced and some criterion of correctness.

Quasi-rational Organizing Principles

As indicated earlier, most cognitive activity is located roughly midway between the poles of the cognitive continuum; thus the major form of cognitive activity consists of the application of "common sense," or "plausible inferences" (Heider, 1958; Polya, 1954) or the application of a variety of "heuristics" (Polya, 1954; Tversky & Kahneman, 1974), that can be described as "quasi-rational" (Brunswik, 1952, 1956), or "good enough" (Simon, 1979) to a variety of "ill-structured problems" (Newell & Simon, 1972), or a "semi-erratic" environment (Brunswik, 1952, 1956). What are the requirements for quasi-rational organizing principles? As in the case of the polar organizing principles, quasi-rational organizing principles must be functionally compatible with those task conditions that induce quasi-rational cognition. That is, in congruence with the Cognitive Continuum Theory, quasi-rational organizing principles must be capable of incorporating information from both sets of conditions, for both will be present in the task. Therefore, such principles must be capable of incorporating subjective and/or objective measurement of the cue data, be capable of incorporating a large or small number of cues, many of which may be contemporaneously displayed and/or sequentially displayed (see Table 1, Appendix A, for further specification).

The weather forecaster, for example, who looks at the data from instruments, and also looks at the sky, incorporates data that are objectively measured with data that are subjectively measured. The resulting forecast thus incorporates the objective cue data read from various instruments in sequence, combined with the data from the many subjectively measured perceptual cues contemporaneously displayed in the sky. Similar examples can be provided by farmer's judgments regarding which crops to plant, physician's judgments regarding diagnoses, etc.; in general, examples can be found in any case in which fully analytical models of the task are unavailable.

Quasi-rational cognitive activity that incorporates both analytical and intuitive properties is functionally compatible with such quasi-rational tasks, not only in the static sense indicated above, but also in a dynamic sense; that is, quasi-rational cognitive activity is capable of moving from one type of activity to the other in relation to the same task. (See the discussion under Premise 4 in Hammond, 1980.) This hypothesized alternation is functionally compatible with quasi-rational tasks because many such tasks are themselves dynamic; that is, they change over <u>time</u>; see Hogarth (1980) for an excellent presentation. Such alternation allows intuitive judgments to check and perhaps revise analytical answers, and vice versa. (There is growing interest in the apparently regular alternation in the dominance of cerebral activity in the right and left hemispheres of the brain; alternation will be discussed in greater detail below.)

<u>Conceptual compatibility</u> requires that the analytical and intuitive aspects of quasi-rational organizing principles must be related to the other properties of these modes of cognition. Thus, for example, according to the conceptual network described in the tables in the appendix, elements of analytical organizing principles must be reported accurately by subjects, although the intuitive elements of intuitive organizing principles will not

be. For example, such heuristics as availability and representativeness (Tversky & Kahneman, 1974), are not described by subjects who use them. The current dispute over the value of verbal reports (see, for example, Ericsson & Simon, 1980) can, therefore, be set aside; the value of such reports depends on the properties of the task and the associated characteristics of cognition induced by them. (Verbal reports are also treated in detail below.)

In short, quasi-rational organizing principles will incorporate some of the properties of intuitive organizing principles and some of the properties of analytical organizing principles; how many, and which, elements of either depends on the number (or proportion, we don't know which) of task properties that can be classified as intuition- or analysis-inducing.

The degree of functional effectiveness of various quasi-rational organizing principles will be dependent on their ability to meet some of the analytical demands for logical defensibility and some of the demands for empirical verification. As task properties become more conducive to analysis, and as the structural and behavioral supports for analysis become increasingly available, cognitive activity will become less quasi-rational; that is, cognition will exhibit more of the (positive and negative) characteristics of a fully analytical system because circumstances make it possible to employ such systems. And, of course, the reverse is true; as task properties reduce the supports for analysis, the (positive and negative) cognitive properties of intuitive cognition, (indicated in Table 1, Appendix A) are induced, and analysis disappears. (See Hammond, 1980, for a discussion of the positive and negative attributes of both modes of cognition.)

Predictions Regarding the Employment of Various Organizing Principles

Intuitive Organizing Principles

Intuition-inducing tasks induce the use of a weighted averaging procedure as an organizing principle (see Anderson, 1973, 1974, for the most detailed theoretical and empirical research regarding this organizing principle; see also Hammond, Stewart, Brehmer & Steinmann, 1975; Hammond, 1980; Hammond, et al., 1980). The weighted averaging procedure refers to the circumstance in which many contemporaneously displayed cues are weighted, added, and divided by their weights. This prediction is not only specific but singular; no organizing principle other than a weighted averaging procedure is apt to be employed in the polar task circumstances defined as intuition-inducing.

Analytical Organizing Principles

In sharp contrast to the singularity of the above prediction, in those tasks defined as analysis-inducing, subjects will employ a variety of principles for organizing information. Such principles include, for example, (a) mathematical logic (e.g., simultaneous equations in word-algebra problems), (b) statistical logic (e.g., Bayesian or Fisherian statistics in situations involving uncertainty), (c) propositional logic (e.g., modus tollens, modus ponnens), (d) problem solving strategies (such as opening and end-games in chess), (e) scientific laws and formuli (as in physics and chemistry), and (f) ideological maxims (in political debates), and other principles more specific to problems more restricted in scope (e.g., puzzles involving mechanical arrangements).

Quasi-rational Organizing Principles

When task properties induce quasi-rational cognition, organizing principles will, as indicated above, contain elements of both types of the polar organizing principles described above. The precise manner in which this combination occurs can best be explained by considering in some detail the shifting locus of vicarious functioning in intuitive and analytical cognition.

The Shifting Locus of Vicarious Functioning in Cognition

Vicarious functioning refers to (a) the substitutability of cues and (b) the substitutability of responses on the part of the organism with regard to goal achievement. In the '30s and '40s these phenomena were described on the perception side as "cue-family hierarchies" by Brunswik (1952, 1956) and on the goal achievement side as "habit-family hierarchies" by Hull (1934). The emphasis given to the concept of vicarious functioning by Tolman and Brunswik (1935) (see also Heider, 1958) marks one of the major theoretical innovations of the 20th century. Yet this concept has still not been given either the prominence or elaboration it deserves in psychological theory in general, nor in cognitive theory in particular; for example, no generally accepted term exists that refers to this type of behavior. (Because the term "vicarious functioning" will be unfamiliar to many readers, it will occasionally be accompanied here by the words "mutual substitutability" in order to reduce terminological barriers.)

To be concrete, vicarious functioning refers to the capacity of an organism to use a variety of cues, as, say, in the perception of size, distance, etc. Thus, for example, if the cue of interposition (nearer object blocking out a part of the appearance of a more distant object) is not available in the environment, human beings can use the textural gradient cue (coarseness in the foreground yielding to a finer texture in the distance) instead, and vice versa. Thus, one cue functions "vicariously" for another. (This description of perceptions is not, of course, unanimously accepted; cf. Gibson, 1979, for a different approach. Irrespective of differences in current theories of perception the Brunswikian approach is the source of this concept.)

As Postman and Tolman (1959) put it subsequent to Brunswik's death: "Cues can be used interchangeably so that different patterns of cues can lead to equivalent results. Similarly, different motor responses can result in equivalent behavioral achievements. This is the principle of vicarious functioning which is the essential underpinning of adjustment to an environment which remains partly erratic" (p. 553). Despite its obvious relevance to cognition, however, few judgment and decision theorists have given this important concept a central place in their work. Einhorn, Kleinmuntz and Kleinmuntz (1979) do, however; indeed, they argue that: "The process of vicarious functioning by which equivalent judgments can result from different patterns of cues is central to any theory of judgment" (p. 465).

Vicarious mediation is a parallel concept that carries the same meaning as vicarious functioning (mutual substitutability) but applies to the environment rather than the organism. This term was also introduced by Brunswik and is linked to the term "redundancy" used by information theorists. The combination of vicarious functioning and vicarious mediation links the flexibility of the behavior of higher organisms to the semi-erratic "causal texture of the environment" (Tolman & Brunswik, 1935) and provides the basis for the "lens model" of behavior (Brunswik, 1952, 1956). Because high degrees of vicarious functioning (mutual substitutable cues in perception, and mutually substitutable means to an end with regard to goal achievement) are observed in all higher organisms, it is presumed to be an adaptive mechanism that provides selective advantage for an organism in an environment that offers a high degree of vicarious mediation. Unfortunately, few analyses have been made of the amount of vicarious mediation offered by specific naturalistic environments in which human beings judge, decide and solve problems. (Brunswik, 1956, considered such analyses to be "propadeutic" to the development of a "functional psychology;" Brunswik, 1956, p. 119ff; see also Hammond, 1980, in which a theory of task structure is described.)

An example of what such propadeutic analyses offer for the work of cognitive psychologists is provided by the list of costs and benefits of vicarious mediation put forward by Einhorn, et al. (1979). They indicate that the <u>benefits</u> of cue redundancy (vicarious mediation) are these: "(a) Information search [can be] limited without large losses in predictive accuracy; (b) attention [can be] highly selective; (c) dimensionality of the information space is reduced, thereby [reducing] information overload; (d) intersubstitutability of cues is facilitated (Hammond, 1972);

and (e) unreliability of cues is alleviated by having multiple measures of the same cue variable" (p. 466).

Einhorn et al. (1979) then list the costs of cue redundancy (vicarious mediation) thus: "(a) Trade-offs between cues are problematic when they are correlated . . . (b) Although selective attention is aided by redundancy, it is still possible that some attentional effort will be wasted on cues that are not marginally predictive (i.e., ecologically valid: KRH). (c) The belief that one has made use of many cues in forming one's judgment (Shephard, 1964), together with (b) can lead to over-confidence (Oskamp, 1965; Ryback, 1967). (d) The difficulty of learning from outcome feedback has been found in studies of multiple-cue probability learning and interpersonal learning (e.g., Lindell & Stewart, 1974; Mumpower & Hammond, 1974)" (p. 467). (Empirical studies of the effects of vicarious mediation have been carried out by Armelius, 1979; Armelius & Armelius, 1974, 1975; Brehmer & Hammond, 1977; Lindell & Stewart, 1974; Mumpower & Hammond, 1974; Knowles, Hammond, Stewart & Summers, 1972; and Knowles, Hammond, Stewart & Summers, 1971.)

Such analyses enhance our ability to understand the relation between task properties and the forms of cognitive activity induced by them. Thus, for example, the above remarks by Einhorn et al. (1979) indicate that differences in the degree of vicarious mediation (cue redundancy) in cognitive tasks induce differences in the degree of vicarious functioning in the behavior of the organism. That relationship is made explicit in the predictions put forward in the tables in the appendix to this report.

The Shifting Locus of Vicarious Functioning in Relation to Intuitive and Analytical Modes of Cognition

The present theory argues that although vicarious functioning occurs with respect to cues in intuition-inducing tasks, vicarious functioning occurs in connection with organizing principles in analysis-inducing tasks. As task properties induce cognition to shift from intuition to analysis, vicarious functioning shifts progressively from the proximal to the central region of the cognitive system. Specifically, at the intuitive pole of the cognitive continuum the organizing principle remains fixed in its form as a weighted averaging procedure; it is cue utilization that is vicarious; that is, cues may be added, omitted, or substituted for one another, either because the environment changes or the organism seeks them out; and cue weights may change as new cues are added or omitted. The organizing principle remains the same, however; it is a biological universal for man (and perhaps other complex organisms as well).

The reverse situation holds at the analytical pole; for any given task cues are fixed in their number and content, but organizing principles will be substituted for one another during the problem solving process. Thus, for example, a physics problem offers fixed information; in order to solve it the subject must search for the correct organizing principle (algorithm) among competing organizing principles. A condensed version of this argument appears in Table 1 below.

	Intuition	Analysis
cues	variable	fixed
organizing principle	fixed	variable

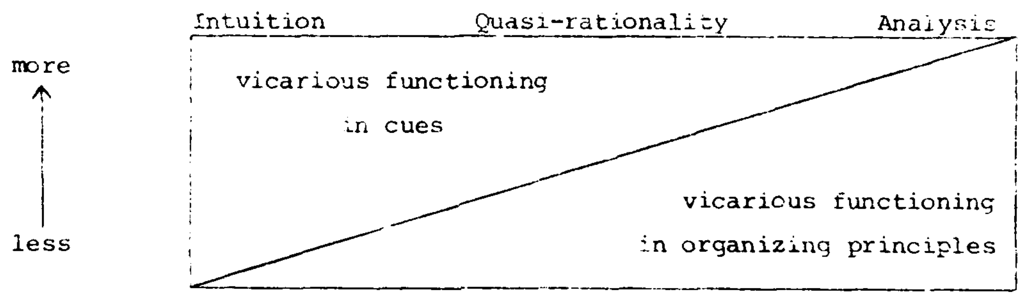
At the intuitive pole, cues are rarely if ever perfectly mutually substitutable; that is, ecological intercorrelations among cues rarely, if ever, reach unity in natural environments (although a propadeutic environmental analysis might teach us otherwise).

The extent to which the subject can find perfect mutual substitutability among analytical organizing principles depends on their mutual substitutability in the nomological network of the analytical principles. In a highly tautological system such as mathematics, for example, a high degree of such mutual substitutability exists; it can be found by a subject with the requisite knowledge. That is, the same answer may be produced by numeric, algebraic, geometric or other equivalent mathematical means. As the task becomes more substantive in form, and thus becomes reduced to the nature of a mechanical puzzle, the mutual substitutability of analytical organizing principles will be reduced. There is no substitutability between the principles employed in the solution of the nine-dot problem, say, and the repairing of a watch. In short, the greater the substantive constraints, the less substitutability to be found among formal organizing principles.

The Role of Vicarious Functioning in Quasi-rational Cognition

The above table is described as "condensed" because it describes the locus of vicarious functioning only at the polar extremes of the cognitive continuum. In the more frequently occurring tasks that lie between these polar extremes and that induce quasi-rational cognition, a more accurate representation is the following:

Table 2



The diagram in Table 2 thus represents the continuous nature of cognition and, in particular, indicates that quasi-rational cognition involves vicarious functioning of cues as well as vicarious functioning of organizing principles. The diagram is intended to indicate that at the intuitive pole of the cognitive continuum, vicarious functioning appears a part of the process of visual perception; it occurs at the proximal region of the organism in the form of the intersubstitutability of such cues as linear perspective, interception, textural gradient, etc. As task conditions reduce the role of visual perception, and concomitantly the role of intuitive cognition, and as analytical cognition increases, quasi-rational cognition increases, and therefore, vicarious functioning will appear at the central, as well as at the proximal, region, and will be manifested in the appearance of more than one organizing principle. At the analytical pole perception disappears; logically based organizing principles now determine solutions. (This description of the most frequently occurring form of cognition is consistent with the difficulties all human beings experience in their efforts to communicate their cognitive work to one another, as well as the difficulties all human beings experience in attempting to reduce disputes that arise from the quasi-rational process of judgment and decision making.)

The study of risk analysis (loosely termed "risk perception," (Slovic, Fischhoff, Lichenstein, Derby & Keeney, 1981) provides a useful means for illustrating the shifting locus of vicarious functioning. Suppose naive subjects are presented with an ecologically representative aerial (pictorial) view of a nuclear power plant located in the midst of a metropolitan center, and are asked to judge the degree of risk to which the citizens in the surrounding area are susceptible. In this task, the subjects are faced with task conditions located near the intuition-inducing pole of the cognitive continuum. Such task properties induce <u>both</u> perceptual-intuitive cognition and analytical cognition, and thus, quasi-rational cognition. That is, various perceptual cues such as density of housing, population of persons, etc. will be contemporaneously displayed and subjectively measured by the subject. Vicarious functioning will therefore occur at the proximal region. This perceptual material will be organized into a part of the judgment of risk by a weighted average organizational principle. But the perceptually-derived material must also be organized or integrated with what the subject already knows or believes (not perceives) to be true about the dangers of nuclear plants. As the subject brings these intuitive and analytical forms of cognition together (the perceptual, intuitive material rapidly and unconsciously, the analytical material slowly and with more awareness) a variety of organizing prinicciples will be employed at the central region: The more the subject knows (or believes she/he knows) about the manner in which nuclear plants function and the specific structure of the plant under consideration, the greater the number of organizing principles that will be available to him/her, and the more aware of them the subject will be. Thus, vicarious functioning will occur at both proximal and central regions in accord with quasi-rational cognition. But if the risk associated with a nuclear plant is to be calculated wholly analytically (as, for example, engineering reports such as the Rasmussen Report purport to do), then perceptual functions will not be involved at all; there will be no risk perception, for we have now reached a form of pure analysis in which perception has no function.

As a further illustration of the shifting role of vicarious functioning in this example, consider the movement along the cognitive continuum in the opposite direction, from full (engineering) analysis to quasi-rational organizing principles. Should it turn out that not every aspect of the analysis of risk regarding the nuclear plant can be fully justified from a wholly analytical procedure, then the door will open to quasi-rationality, for judgments will be induced (persons will begin to discuss the "weight" or "relative importance" of various "factors"), and quasi-rationality will increasingly replace analytically-produced answers. Quasi-rational organizing principles will appear, together with their associated properties of low awareness, lack of retraceability, lack of consistency, and other properties noted in Table 1 (Appendix A). Controversy and debate will now occur because it is precisely at the point where judgments produced by quasi-rational cognitive activity will be applied that different organizing principles, explained and described with greater or lesser degrees of awareness, will be brought to bear on a bounded set of fixed, stable data.

If task conditions induce cognitive activity to move increasingly further away from the (perhaps false) security of full analysis toward even greater degrees of intuitive cognitive activity, vicarious functioning will be increasingly reduced in scope at the central region, cognition will become less conscious, and the organization of information will occur more rapidly; cues will now begin to function vicariously and begin to be employed with reduced awareness, and we return to those appraisals of risk that combine intuition and analysis (and which are inevitably employed to form social policy; see, for example, Hammond, 1978; Hammond & Adelman, 1976; Hammond, Rohrbaugh, Mumpower & Adelman, 1975; see also Slovic et al., 1981). If task conditions require the risk appraisers to increase further their reliance on visual perception, or otherwise increase their reliance on task conditions that induce intuitive cognition, then we will have returned to the first situation described above; judgments will be almost wholly a function of an intuitive organizing principle, the weighted average procedure. Thus, the differential locus of vicarious functioning marks a major difference between cognition that produces judgments, and cognition that produces answers. (Of course, the current use of the term "risk perception" to cover all of these task conditions is inappropriate; it obscures the distinction between intuition and analysis.)

Summary

The concepts of vicarious functioning and vicarious mediation were introduced and described and their importance for theories of cognition indicated. The shifting locus of vicarious functioning from the proximal/peripheral region of the organism to the central region as task properties induce cognition to move from intuition to analysis (and vice versa) was also described. An illustration of the application of this aspect of the Cognitive Continuum Theory to a real world problem was also provided.

The hypothesis regarding the shifting locus of vicarious functioning from cues to organizing principles as cognition moves from intuition to analysis (and vice versa) deserves both theoretical and empirical exploration in its own right, but in this report we explore its potential for unifying what are now disparate, noninteracting approaches to cognitive psychology, primarily the work in problem solving and the work in judgment and decision making. (See Pitz & Warren, 1980, for an integration of information processing and decision theoretical approaches in relation to vocational choice; see also Einhorn et al., 1979, for a detailed linkage between judgment and process analysis; see Estes, 1980, for a discussion of judgment and decision behavior in the field of cognition generally; see also Wallsten, 1980.)

The Implications of Shifting Vicarious Functioning for a Unifying Theory

It is a curious but undisputable fact that there is virtually no serious interchange between theory and research in problem solving and theory and research in judgment and decision making. The author index to Simon's (1979) collected papers contains the names of only two of the names contained in the author index of a review of the six major approaches to judgment and decision research by Hammond et al. (1980). And the reverse is also true; the author index of the latter contains almost none of the names of the authors in Simon's book.

There are, no doubt, several reasons for the disparate paths taken by students of judgment and decision making and students of problem solving. But at least one reason for the divergence was made clear by Simon in 1957 in an introduction to a reprinting of a number of his papers (Simon, 1957). There he takes pains to distinguish his view of human cognitive activity from that of contemporary prominent judgment and decision theorists (e.g., Savage). After acknowledging their many positive contributions, he states:

> Having said this, I must record my judgment, which is at the present time very nearly the judgment of a minority of two, that the approach taken in the theory of games and in statistical decision theory to the problem of rational choice is fundamentally wrongheaded. It is wrong in precisely the same way that classical economic theory is wrong -- in assuming that rational choice is choice among objectively given alternatives with objectively given consequences that reflect accurately all the

> complexities of the real world. It is wrong, in short, in ignoring the principles of bounded ration[illegible] to erect a theory of human choice on the unrealistic assumptions of virtual omniscience and unlimited computational power. (p. 202)

This explicit distinction led to, or at least has been associated with, disparate approaches to cognitive psychology from then until now, despite the fact that considerable overlap existed between Simon's concept of "bounded rationality" and Brunswik's concept of "quasi-rationality" (Brunswik, 1952, 1956; see Hammond, 1980, pp. 27-40, for a discussion of the relation between them, which Simon never seems to have noticed, although their work on this topic appeared at about the same time; there are no references to this concept in any of his books or papers.) But the "minority of two" has increased to what is now a majority that includes even a majority of judgment and decision researchers, particularly since the introduction of the work on heuristics by Tversky and Kahneman (1974; Kahneman & Tversky, 1979). "Bounded rationality" (or the concept preferred here, "quasi-rationality") is the theme that is serving to identify common points of view among workers in the fields of problem solving and judgment and decision theory.

Simon's general description of bounded rationality indicates that it meets our criterion of functional effectiveness. For example, he indicates (p. 3) that "Satisficing provides an escape from the difficulty that, in a complex world, the alternatives of action are not given but must be sought out. Since the search generally takes place in a space that is essentially infinite, some stop rule must be infused to terminate problem solving activity. The satisficing criterion provides that stop rule: Search ends when a good enough alternative is found." But Simon offers no specification of the boundary for the functional effectiveness of bounded rationality, yet such a boundary certainly must exist. Clearly, satisficing is functionally effective only in those task circumstances when "good enough" is acceptable; but perfectly determined, wholly analytical, error-free tasks will not accept approximate answers.

Bounded rationality also appears to meet the criterion of functional compatibility (compatibility of the organizing principle with properties of tasks) that share some characteristics with those employed by judgment and decision theorists, thus: "Satisficing also provides a solution to another problem of complexity . . . . When the criterion of problem solution or action has more than one dimension there is the matter of calculating the relative merits of several alternatives, one of which may be preferred along one dimension, another along another. The economist, unconcerned with the boundedness of rationality (concerned only with the analytical pole of cognition: KRH) solves the problem with the help of marginalism . . . . The satisficing rule, which requires no such calculation . . . stipulates that search stop when a solution has been found that is good enough along all dimensions (italics in original)" (p. 3). This description brings Simon closer to the judgment and decision researchers, but, curiously, further from problem solving research. For many of these tasks employed by Simon and his colleagues in their studies of problem solving will not accept answers that are merely "good enough." For example, because the Tower of Hanoi problem and the missionary-cannibal problem are wholly determined, error-free tasks, they will not accept answers that are less than perfect, that is, answers that do not solve the problem. "Good enough" may apply to the methods (the heuristics) by which the answer is achieved in these tasks, but not to the answer. In other task situations (e.g., those with the task properties indicated in Table 1, Appendix A) that induce quasi-rational cognition "good enough" may, and it is argued here, does, apply to both method (or process) and answer.

In addition to what appears to be a lack of specification regarding task conditions to which the concept of bounded rationality applies, it also fails to achieve a high degree of conceptual compatibility; that is, its relationships with other psychological processes, its nomological network, is not clear as it might be. The difficulty is that its relationship to the psychological processes that are used to describe the cognitive activity in specific problems or task situations is not indicated. The term "bounded rationality" or "satisficing" does not appear as an explanatory principle in connection with experimental work in problem solving; it is not referenced in the 1979 collection of Simon's papers, save for its appearance in the original 1955 and 1956 papers. (See Hammond, 1980, for further examples.)

In short, despite the wide use of this concept, it remains detached from experimental work. Therefore, it is not surprising to find criticism of the gap between theory and practice. For example:

> The primary problem with bounded rationality and heuristic theories has been stated succinctly both by Pitz and by Slovic,

Fischhoff and Lichtenstein:

". . . as yet the assault on normative approaches to decision theory led by the concepts of bounded rationality and heuristic theory, has not been developed to the point where a systematic model will lead to test able predictions. The experimental support for these alternatives consists mostly of demonstrations that, under appropriate conditions, subjects will behave in an irrational manner" (Pitz, 1977, p. 420).

". . . the evidence . . . suggests that the heuristic selected, the way it is employed, and the accuracy of the judgment it produces are all highly problem-specific; they may even vary with different representations of the same problem. Indeed heuristics may be faulted as a general theory of judgment because of the difficulty of knowing which will be applied in any particular instance" (Slovic, Fischhoff & Lichtenstein, 1977, pp. 5-6).

The problems with these theories as they are now formulated in no way detracts from the important experiments they have inspired. The experiments have demonstrated convincingly that judgment is influenced by the task, that different features of the task are attended to and processed under different circumstances, and that simple algebraic or normative models will not describe judgment in any satisfying and complete fashion. Thus, "bounded rationality" and "heuristic" theories

> should not be abandoned. Rather, they should be formulated in such a manner that they apply over a range of situations but can be tested rigorously in any particular situation. (Wallsten, 1980, p. 220) [Note: cf. Brunswik 1952, 1956; Hammond, 1966.]

One way to close this gap is by observing the shifting locus of vicarious functioning in relation to intuitive and analytical organizing principles. We begin by showing the convergence of the concept of vicarious functioning and "shifting strategies."

<u>Vicarious Functioning of Organizing Principles and "Shifting Strategies"</u>

Simon's emphasis on "shifting strategies" (Simon & Reed, 1976; Simon, 1975) in problem solving is clearly compatible with the proposition regarding the vicarious functioning of analytical organizing principles. ("Shifting strategies" include, for example, such specific strategies as "balance" and "means-end" strategies in the missionary-cannibal puzzle.) The explicitly general strategies (such as "means-end") are called "heuristics" in much the same sense as Polya (1954) used the term, and much as it is used by Tversky and Kahneman (1974), who, unfortunately, also on occasion refer to certain heuristics as "cues" (see Hammond et al., 1980, for comment). These strategies are organizing principles, or heuristics, that are "good enough." Such organizing principles are to be sharply distinguished from fully analytical <u>algorithms</u> (see Polya, 1954).

The conclusion that organizing principles change ("shift") during the course of problem solving is consistent with the hypothesis offered here with regard to the locus of vicarious functioning in analysis-inducing tasks (such as Tower of Hanoi and the river-crossing tasks such as "missionary-cannibal"). We explore this similarity in view further below, but first we explore further similarities between judgment and decision research and problem solving research with regard to descriptions of task environments in terms of their formal and substantive character.

Formal and Substantive Descriptions of Task Environments

Simon and Hayes (1976) approach this distinction in this way:

> The problems used in this study were thirteen variants of a single problem, all formally isomorphs of the Tower of Hanoi puzzle. That is to say, successive situations in these task environments could be mapped in one-to-one fashion, on arrangements of disks on pegs in the Tower of Hanoi puzzle; and legal moves for each of the problems could be mapped into legal moves of the Tower of Hanoi. In fact, any of the problems could have been solved by mapping it into the corresponding Tower of Hanoi problem and then solving the latter. No subject did this, and only two or three even thought of trying, or noticed the analogy. The problems, then, were identical in formal structure, but differed in their "cover stories." (see p. 478, Simon, 1979)

Thus, Simon and his colleagues describe the difference between the formal structure of the task and its various substantive "cover stories." A similar distinction has been made for some time in judgment and decision research (see, for example, Hammond, 1966, pp. 68-75; see also Hammond et al., 1975; Hammond et al., 1980). The distinction is also explicit throughout Brunswik's (1956) description of the need for the representative design of experiments. He protests against the gratuitous generalization of results obtained from experiments (or "task environments") that are formally identical to those task environments which are formally different, and insists (correctly) that such overgeneralization is a common, pervasive error in psychological research. (And so it remains; see Hammond & Wascoe, 1980, for descriptions of current examples of work that results in extravagent overgeneralization in social psychology.)

There is a parallel in judgment and decision research to the work Simon and his colleagues have done with regard to the variety organizing principles developed by their subjects in task environments that have a singular formal structure, but present different "cover stories" to the subjects. For example, Anderson (1974) and his colleagues use judgment tasks that are formally identical, but which offer different substance (or content), and their subjects' behavior is also examined with regard to the different organizing principles (e.g., adding rule, averaging rule, etc.) such "cover stories" induce in the subject.

There is a clear difference, however, between the organizing principles evoked by the Tower of Hanoi and its problem isomorphs and those evoked by judgment tasks and their formal isomorphs such as those used by Anderson and other judgment and decision researchers. One such difference is that the organizing principles evoked by the former are reportable strategies; that is, the subjects report their strategies to the experimenter (who then attempts to model them). In the latter case, organizing principles are (almost) never reported. This brings us to the theoretical basis of "reportable" and "nonreportable" organizing principles.

Verbal Reports

Acknowledgement of the shifting locus of vicarious functioning renders spurious the debate between those who argue that verbal reports concerning cognitive activity are useful because they are accurate and complete (e.g., Ericsson & Simon, 1980) and those who argue that such reports are neither, and therefore useless (see, e.g., the work by judgment and decision researchers generally; see also Nisbett & Wilson, 1977, for a review).

The debate can readily be resolved by observing that in general those who have argued for the utility of verbal descriptions of cognitive activity have concerned themselves with behavior in problem solving tasks; that is, with the behavior of persons consciously attempting to employ a variety of analytical organizing principles that will produce a perfectly correct answer in a task situation that will accept nothing less. In these task situations, where vicarious functioning occurs in relation to organizing principles (or heuristics) that will be consciously manipulated or changed by the problem solver, it should not be surprising that verbal reporting would be found to be accurate and useful. And, of course, the manipulabilitiy of task materials makes verbal reporting of cognitive activity easy for the subject; such motor activity provides visible, structural support for recall and reportability. On the other hand, those researchers who study human judgment in task situations that induce quasi-rationality, rather than analysis, are studying behavior in situations in which vicarious functioning occurs at both the proximal region and at the central region. As a result, they find verbal reporting of cognitive activity to be less accurate, as they should; vicarious functioning at the proximal region is not under conscious control. And, of course, task materials are not manipulated in judgment and decision research, and this structural support for recall is not available. As task properties induce the subject to become more intuitive and less analytical, and thus to employ the weighted average procedure in the process of organizing information into a judgment, verbal reports become less accurate; more to the point, verbal reports begin to serve a different purpose for the experimenter. They indicate artifactual constructions that mislead during the process of social interaction, thus impeding interpersonal learning and increasing interpersonal conflict (as judgment and decision researchers have found in their research; see, for example, the work by Brehmer and his colleagues; e.g., Brehmer & Hammond, 1977).

To be specific, subjects should not report with competence regarding the principles they employ to organize information in intuition-inducing tasks, for (as indicated above) if the subject is confronted with a large number of contemporaneously displayed cues that require subjective measurement, the subject will be unable to specify with exact accuracy which cues were utilized, or to report accurately on the relative weights assigned to the cues that were utilized, much less to indicate whether the weighted cue values were added, and even much less whether they were divided by the products of the weights for each cue (see tables in the Appendix). Nor should subjects report completely and accurately on their cognitive activity in those task situations that induce quasi-rational cognitive activity, where they employ both types of organizing principles; for in such task situations they are aware of only part of their cognitive efforts.

The matter of the utility of verbal reports is embedded in another issue as well, however, and that concerns the paramorphic (Hoffman, 1960) status of an organizing principle, a topic that, in spite of its significance, has been neglected in relation to the discussion of the accuracy of verbal reports.

The value and necessity of paramorphic descriptions of principles of organization. Two types of objections have been raised against the utility of using descriptions of principles of organization that are statistical models (e.g., weighted average). One is that no subject has ever reported engaging in such cognitive activity; another is that subjects could not possibly engage in it. Failing to accept the paramorphic nature of such models (see Wallsten, 1980, pp. 216-217) in favor of molecular "list structures" of a sequence of cognitive operations creates a clear and definite gap between problem solving research and judgment and decision research. For the vast majority of judgment and decision researchers do accept the value and necessity of the concept of a paramorphic model (introduced with skill and cogency by Paul Hoffman in 1960; Hoffman, 1960). And as we shall see immediately below, the concept of a paramorphic description of cognitive activity not only can, but is, used in a valuable and necessary way in problem solving research; it describes how strategies "shift," that is, how one problem solving heuristic is given up for another.

It may well turn out that the well-known predictive utility of the weighted average procedure is somehow false and misleading. But the fact that subjects do not report such cognitive activity should not weigh against the plausibility of its explanatory value, nor should the argument that subjects can not report such activity weigh against the plausibility of its explanatory value. Subjects do not report the fact that the gas laws describe their respiratory activity, or the fact that other physical and chemical laws control other physiological functions, nor could naive subjects ever be expected to do so. In short, the value of paramorphic models of intuitive and quasi-rational organizing principles need not be questioned on these grounds. The plausibility of the explanatory value of the weighted average procedure must rest on (a) its empirical predictive validity and (b) its coordination with the other concepts in the conceptual framework that accounts for all cognitive activity. Reportability is irrelevant to questions of valid representation. I now turn to a specific experiment which will provide an empirical example of utility of a unified approach.

The Function of A Paramorphic Judgment Model in Problem Solving Research

In the context of constructing a model of the cognitive processes employed in the missionary-cannibal river-crossing problem, Jeffries and her colleagues (Jeffries, Polson, Razran & Atwood, 1977) indicate that a major component of their model is an "evaluation process" (p. 416). (That evaluation process is what any judgment researcher would recognize, and describe, as a judgment process.) The evaluation, or judgment, occurs at the stage of problem solving when the subject makes ". . . [an] assessment of how close each problem state is to the goal . . . We assume that this function will be a weighted sum (note the close approximation to weighted average: KRH) of components which reflect possible solution strategies . . . of the form $e_i = aM_i + bC_i + cP_i$, where e_i is the value of the evaluation function for state i, in which there are M_i missionaries, C_i cannibals, and P_i missionary-cannibal pairs on the right bank" (p. 416). It is particularly important to note that this is a paramorphic representation of the organizing principle that occurs in-between moves taken to solve the problem, and that it produces an evaluative judgment, one that evaluates the distance between the results of a move and where one wants to be. Note also that it is an evaluative judgment that has many (but not all) of the characteristics of intuitive cognition listed in Table 1 of the Appendix.

The paramorphic nature of this organizing principle is recognized by the authors, although they do not label it as such; thus: "We do not assert that the problem solver actually performs the operations defined by [the weighted sum procedure] to generate his estimate of the desirability of various states. We only claim that [the weighted sum procedure] and the strategies that the problem solver actually utilizes will produce equivalent rank orderings of the states of the problem" (p. 417); cf. Hoffman (1960). This mode of cognition is, therefore, quasi-rational, not wholly intuitive, because the values of the few (3) cues are <u>not</u> subjectively measured by the subjects. That aspect of the organizing principle is, therefore, reportable by the subject, but the (paramorphic) weighted sum organizing principle is not. Thus, the "evaluation function" (the weighted sum) is the quasi-rational ("bounded rational") organizing principle that is "good enough" for providing a choice of the next move. Here, then, is the explicit representation of quasi-rational cognition (bounded rationality) a representation not previously found in the computer models of thought developed by Simon and his colleagues subsequent to his introduction of that concept in 1955. There are many indications in Simon's previous work, however, of the recognition of this form of quasi-rationality and even its relation to <u>judgment</u>.

In 1962 Newell, Shaw and Simon (see Simon, 1979, p. 149) mentioned (under the heading "Preliminary View of Problem Solving Processes") that

> One useful distinction differentiates processes for finding possible solutions . . . from processes determining whether a solution proposal is in fact a solution . . . This is a distinction that is often made in the literature in one set of terms or another (recall that these authors are writing in

1961: KRH). Johnson (1955), for example, distinguishes "production" processes from "judgment" processes in a way that corresponds closely to the distinction we have just made. We prefer to call the first class of processes solution generating processes, and the second class verifying processes" (italics in original as indicated) (p. 149).

This paragraph is followed by one describing "solution generating processes" but there is no further discussion of the "verification process," that Johnson called a judgment process, nor is this term indexed. And it is not easy to find "verification processes" explicated, represented or described in the computer models of thinking that are presented by Simon and his colleagues. "Judgment" (perhaps because of its association with the approach taken by those "wrongheaded" judgment and decision theorists?) seems to have no readily identifiable place in Simon's cognitive theory. But it should have, and its recognition will help to clarify the distinction between "generation" and "verification;" both need explication, even though only the former seems to have received it.

The introduction to the "evaluation function" by Jeffries et al. (1977) provides the needed distinction between the process that (a) generates heuristics ("balancing" or "means-end" strategies in the missionary-cannibal puzzle) and (b) the process of choosing between these heuristics that assigns different weights (a concept never employed by Simon but invariably employed by judgment and decision researchers) to cues. The study also illustrates the role of quasi-rationality (bounded rationality) in providing <u>feedback</u> for the problem solver regarding the utility of the choice of moves in tasks which do not provide immediate outcome feedback.

For example, the "evaluation function" in Jeffries et al. (1977) clearly refers to the process of evaluating the utility of the <u>next</u> move, i.e., <u>planning</u>. Newell et al. (1962), on the other hand, refer to "verification," that is, the evaluation of the utility of a <u>past</u> move; an evaluation or judgment that offers the subject <u>feedback</u> in terms of subjective appraisal of a past move. The evaluation of a past move by the subject is a judgment of critical importance because there is no ostensible feedback information provided by the task itself (e.g., a light does not flash on or off) with regard to the utility of any move. Therefore, the subject who engages in that evaluation is exercising his/her judgment regarding whether the move was a valuable one, i.e., one that moved him/her closer to the goal. (See, specifically, Figure 3 in Jeffries et al., 1977.) As a result, Jeffries et al. (1977) bring into functional contact (a) the (paramorphic) organizing principle so frequently alluded to in judgment and decision research with (b) the (reportable) information processing model so frequently employed in problem solving research. In so doing, they provide a step toward the unification of cognitive theory.

Nor am I alone in believing that Jeffries et al. (1977) provide an integrating link between these fields. Einhorn et al. (1979) also note (p. 480-481) the relation and provide this comment:

> The [study] by Jeffries et al. (1977) concerns solving river-crossing problems (missionaries-cannibals, hobbits-ocrs,

> etc.). They propose a weighted linear model and cutoff criterion for evaluating the sequential moves in such problems. In particular, the three cues that are used are the number of missionaries, cannibals, and missionary-cannibal pairs on the right bank of the river. Furthermore, the weights given to these cues reflect differences in strategy (means-end vs. balance, etc.). Although this formulation is part of a more complex model that they develop, its similarity to our position is striking. (p. 480-481)

The "more complex model" to which Einhorn et al. (1977) refer is the simulation of the molecular structure of each of the strategies (heuristics) that are employed in this problem. (See Figures 1 & 2 of Jeffries et al., 1977.) Thus, we are brought to the question of the relation between (a) the execution of an organizing principle (a heuristic) and (b) the evaluation process just described (that of planning a new move and/or evaluating the effectiveness of a past move).

Heuristics and Their Prior and Past Evaluations

The missionary-cannibal task is highly analysis-inducing; by the criteria of the tables in the Appendix it does not lie at the polar extreme of the cognitive continuum, but it is nearby. For although the task demands analysis, and can be solved by an analytical procedure, it is one for which the subject has no prior training and therefore has no algorithm clearly available for solving it. In this regard it resembles the tasks often employed by judgment and decision researchers who require subjects to "solve" the problem of choosing between gambles or solve statistical problems without the aid of the knowledge of the calculus of probability. The task is thus one step or one position to the left of the analytical pole in the direction of the intuitive pole of the cognitive continuum. In this task the balance strategy is apparently employed first, then the evaluation judgment is applied; this sequence is repeated until the failure of the balance strategy is apparent and then the means-end strategy is employed. This changing set of operations leads to two different hypotheses about the manner in which quasi-rational cognition functions: (a) as a compromise between intuition and analysis or (b) as an alternation between them.

Alternation or Compromise

Hypothesis I: Quasi-rational cognition is the result of compromise. This is the position taken by Brunswik (see Hammond, 1980, for an explanation) and the position implied in the use of a weighted average as part of a quasi-rational organizing principle. The judgment is pulled in one direction by analysis and in another by intuition; if quasi-rationality prevails, the result lies somewhere between.

Hypothesis II: Quasi-rationality is the result of an alternation between intuition and analysis in which the work done by one modifies the work done by the other; only one process is fully active at any given moment, however.

The present theory argues that the properties of the task will determine which type of quasi-rationality will occur. If the task will accept judgments that are "good enough," then compromise will occur. If the task properties are such that it lies near the analytical pole of the continuum (see tables in Appendix A) then the task will accept only those answers that purport to be correct.

Statistical methods of analysis and decsription are closely associated with the former tasks because these methods are designed to cope with tasks that will accept approximate answers; the properties of these tasks will not permit anything better. And, of course, we find judgment and decision researchers using the logic and techniques of the statistical methcd in order to understand how their subjects produce approximations, or quasi-rational judgments, that are compromises between intuition and analysis.

Tasks that are analytical in character will induce alternations between intuition and analysis because they will not accept approximate solutions that result from compromise. Arithmetic, algebra, geometry, Newtonian mechanics, the Tower of Hanoi and its isomorphs, for example, do not accept solutions that are "good enough" compromises between intuition and analysis. (See the full text of Polanyi's remarks on "The alternation between the intuitive and the formal . . . at the beginning and end of each chain of formal reasoning," quoted in Hammond, 1980, pp. 75-77.)

In a previous report (Hammond, 1980) quasi-rationality in the form of compromise was described in detail. Here we turn to an illustration of quasi-rationality in the form of alternation. [Note: I am indebted to Robert Quinn for his many suggestions in relation to alternation.]

Alternation, shifts in vicarious functioning, and creativity. The Cognitive Continuum Theory asserts that when task conditions induce quasi-rational cognition, vicarious functioning occurs in connection with cues and organizing principles. This assertion carries implications for problem solving that requires new solutions as well as for problem solving that requires the application of already known organizing principles to new problems. That is, creativity requires the ability to find new ecological relationships among cues as well as new organizational principles. Vicarious functioning in these circumstances thus incorporates the notion of "functional substitutability" as against "functional fixedness" of cues (emphasized by the Gestalt psychologists; see, for example, Duncker, 1945). Failure to achieve substitutability of the ecological relationships among cues is just as much an obstacle to problem solving as failure to achieve substitutability among organizing principles.

Consider, for example, the classical problem solving experiment by Maier (1931), in which the solution of the problem depends on the subjects' ability to change the ecological implication of an object from a "tool" to a "bob" of a pendulum. In this problem, the subject is "shifting strategies," that is, testing one organizing principle (heuristic) after another, and also changing the potential relationships of the various artifacts (that constitute cues) to a solution. Thus, for example, the meaning of the pliers that Maier supplies for his subjects, is, in most environments, that of a tool; but that meaning is useless (carries zero ecological validity) in this task environment; on the other hand, if its ecological function is changed to a pendulum bob, it becomes possible to execute the organizing principle that demands that some object serve as a pendulum bob.

Fortunately, Maier carried out the experiment in such a fashion that the results carry relevance for other concepts in the nomological network of the tables in Appendix A. I use the description of behavior of the subjects in this study provided by Lindsay and Norman because it yields an independent verification of the relation between (a) awareness of the "in-between" cognitive activity, (b) time taken to reach a correct solution, and (c) sequential operations to the (d) predictions in the tables in the Appendix.

> In this experiment two cords hung from the ceiling of a room. The subject's task was to tie the strings together, but it was impossible to reach both at the same time. A number of solutions were possible by clever use of the various objects scattered deliberately but inconspicuously throughout the room. Only one solution was of interest to Maier, however, and he explored the hints needed to get his subjects to come up with it. . . . The experimenter (who was in the room with the subject) used two different hints.

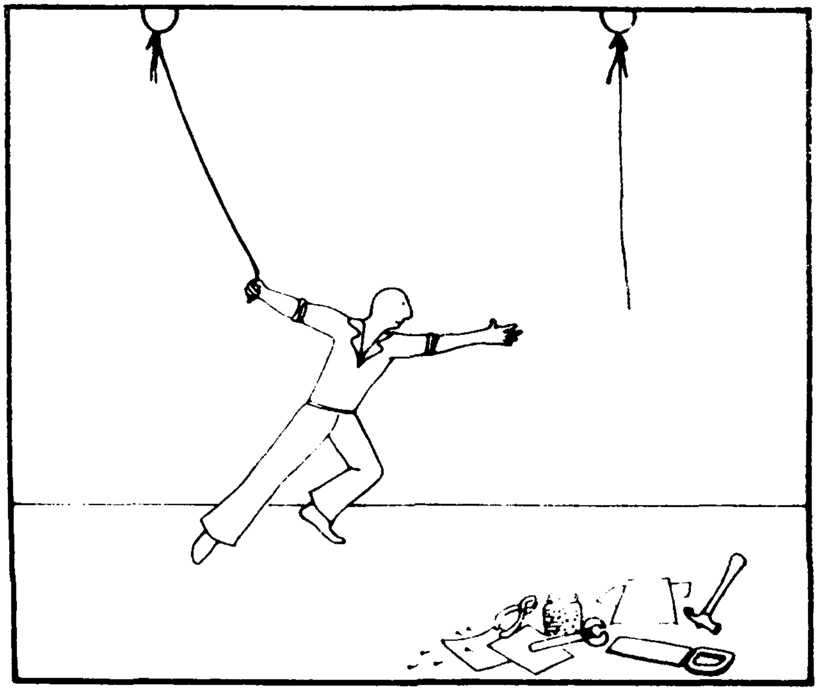


FIGURE 14-8

Hint 1. The experimenter walked about the room, and, in passing the cord which hung from the center of the room, he put it in slight motion a few times. This was done without the subject knowing that a suggestion was being given. The experimenter merely walked to the window and had to pass the cord.

Hint 2. In case hint 1 failed to bring about the solution within a few minutes, the subject was handed a pair of pliers and told, "With the aid of this and no other object, there is another way of solving the problem." [The description of the hints is Maier's, as outlined in the original article (1931).]

[Awareness in relation to contemporaneous displays vs. sequential presentations: KRH]

Maier divided the subjects who successfully solved the problem after receiving the hints into two groups -- those who appeared to solve the problem as a whole ("The solution just came to me; I don't know how"), and those who seemed to go through a series of steps to the solution ("Let's see, if I could move the cord, . . . throw things at it, . . . blow at it, . . . swing it like a pendulum . . . aha!"). The interesting difference between these two groups, from our point of view, is the difference between the subjects' reported use of the hint. Those who solved the problem as a whole failed to report that the hint was of any use to them, while the group that progressed through stages reported (with but one exception) that the hint was an aid. Our question is whether the "whole" subjects actually used the hint without being aware of it. If this is so, then we would expect that protocols taken during problem solving might miss many of the steps involved in arriving at a solution.

[Awareness and time to solution: KRH]

First, it is clear that the subjects who failed to report the use of the hint in fact solved the problem much quicker than the group for which no hints were given. On the average, the majority of subjects found the solution within less than a minute after the hint was given. When no hints were given, only 20% of the subjects found the solution, even though they were allowed to work on the problem for half an hour.

[Awareness and reportability: KRH]

Did the "whole" subjects notice the hint but were perhaps simply unwilling to admit that they used it? This seems unlikely. Subjects who solved the problem in steps seemed to have no hesitancy in referring to the hint as they described their solution. Why should the "whole" subjects hold back? The conclusion seems to be that the hint played an important part in bringing about the solution, even though the subjects were not consciously aware of its role. If the subject does not realize such an obvious step in his or her protocol behavior, then our protocol records are going to be incomplete.

We must assume, then, that as people work on a problem, they proceed through a series of strategies and operations, which are reflected in their verbal description of their own mental operations. The steps going on internally, however, are not all faithfully represented in the verbal output. What we can observe will only be a partial description of the actual internal processes.

The conclusion, then, is that only a portion of a person's cognitive activities is going to be available for external examination. The record will be most complete if people are encouraged to verbalize their detailed thought processes, and if protocols are taken during the actual performance of the activity. Even Maier's "whole" subjects might have been aware of their use of the hint if they had been told beforehand to monitor their thought processes and to talk aloud as they groped for a solution. Despite its shortcomings, the protocol analysis is a powerful tool in attempting to reconstruct the events that go on during problem solving and to explore the kinds of cognitive strategies that operate in these complex tasks. (pp. 557-559)

Lindsay and Norman's (1977) account of Maier's classic experiment is useful not only because of what it does provide but because of what is missing: What sort of cognitive activity is taking place during those "steps going on internally [that] are not represented in the verbal output"? (p. 559) Lindsay and Norman assume that if "people are encouraged to verbalize their detailed thought processes" (p. 559) we may find out. Perhaps. But if cognitive activity in analytical tasks that will not accept approximate solutions (such as Maier's) consists of an alternation between intuitive processes that involve the vicarious functioning of cues <u>as well as</u> organizing principles, and/or in which shifts in weights mean a shift in strategy (as indicated in Jeffries et al., 1977) then such verbalized reports may be wholly misleading; worse still, they may be constructed simply to satisfy the researchers' demands for them.

In short, in analytical tasks where approximate answers are not good enough, cognitive activity alternates between (a) the unconscious production of organizing principles (strategies), and (b) the conscious explication and execution of these strategies, followed by (c) the evaluation of the utility of their execution. The production process is largely intuitive; that is, it is (a) responsive to many cues contemporaneously displayed (see Lindsay and Norman's (1977) above use of "whole") (b) rapid, and unconscious ("the subjects who failed to report the use of the hint in fact solved the problem much quicker" [p. 588]) and produces solutions based on new ecological relationships and new organizing principles, thus involving vicarious functioning of cues as well as organizing principles.

When cognitive activity shifts from production to the explication and execution of the intuitively (as described above; see also tables in the Appendix) produced strategy, the result will be a series of sequential operations carried out with a high degree of awareness and thus subject to accurate and meaningful report. Should the strategy fail, and should no new principle of organization be readily available, cognitive activity will return again to the unconscious production of a new strategy.

The evaluation function, or judgment process, that occurs after the execution of a move, (or a part of the strategy) occurs when the consequences of a move are not apparent. That is, outcome feedback is not immediate and obvious but must be produced by the subject. Jeffries et al. (1977) indicate that such evaluation (judgment) functions may be represented by paramorphic equations of the type (linear model) predicted in the tables in the Appendix. Such judgments may be the result of a compromise between strategies, depending on the level of awareness of the subjects choice of a given strategy. Compromise will be absent if a subject reports the conscious choice of a means-end strategy; moveover, s/he will be able to make a conscious evaluation of a recent move ("that was a mistake") thus providing clear outcome feedback. But if the subject has a low awareness of strategy choice, compromise will be present, and the ensuing judgment will thus provide ambiguous outcome feedback, and slow progress toward solution.

If the above interpretations carry plausibility, then researchers in the field of problem solving should examine the judgment and decision making literature with the aim of discovering what has been learned about judgment processes, so that the largely unconscious process of selecting and evaluating moves can be better described and understood. For example, although it appears to us that steps taken by Jeffries et al. (1977) are most promising, they have not noted the similarity between their remarks about the robust nature of their linear model ("arbitrary changes in the weights . . . make almost no difference in this pattern [of acceptable and nonacceptable moves]"; p. 417) and the well-known work by Dawes and Corrigan (1974) that explored the implications of this aspect of linear models (see also Dawes, 1979) nor any of the several possibilities of enrichment of the description of that process. That is an effort best undertaken in the pursuit of a unified theory.

The Shifting Locus of Vicarious Functioning in Interpersonal Conflict and Interpersonal Learning

The shifting locus of vicarious functioning also has strong implications for the study of interpersonal conflict and interpersonal learning, and thus expands the area of research in cognition to include these topics ordinarily thought to be of interest only to social psychologists. For example, the end result of cognitive activity in tasks inducing elements of intuition and analysis is a judgment that is the result of a compromise between the different contributions of each mode of cognition. (See Brunswik, 1952, 1956, for a detailed theory of perceptual compromise; see also Hammond, 1966, for reviews and critiques; see Hammond & Wascoe, 1980, for a variety of current applications of the concepts of vicarious functioning and compromise in studies of interpersonal conflict and interpersonal learning.) Compromise will, therefore, occur in relation to whatever part of quasi-rational cognitive activity that is controlled by a weighted averaging procedure. Such compromise within one person's organizing principles increases the likelihood of the occurrence of compromises between persons who employ organizing principles that are similar in form (i.e., weighted averages) but different in other respects (i.e., employ different weights or different function forms for the same cues). Such compromises would be expected to be implicit rather than explicit, and, indeed, there is considerable evidence for research in interpersonal conflict to support that view (see, for example, the numerous studies by Brehmer and his colleagues; see Hammond & Wascoe, 1980; Brehmer & Hammond, 1977; Hammond et al., 1975, for reviews; see also the work of Gillis, 1980; Gillis & Moss, 1978; Gillis & Davis, 1977, regarding the effects of psychoactive drugs on conflict and compromise, also in Hammond & Joyce, 1975). Should task conditions induce the demand for analysis, however, differential weights may be made explicit (although these may well differ from implicit weights). If weights do become explicit, then trade-offs can be made explicit, and thus explicit bargaining can occur. If conditions provide incentives for compromise, then the intuitive component of a quasi-rational organizing principle (the weighted average procedure) can become the basis for the development of an analytical principle in which quantitative analysis, bargaining and trade-offs occur in a highly conscious, highly explicit way, for example, "I'll reduce my emphasis (weight) on this if you will reduce your emphasis (weight) on that."

Dispute that begins with differences between highly explicit, analytically-based first principles, rather than the implicit looseness and low degrees of awareness of quasi-rational cognition, is however, far less amenable to compromise. For the end-result of analysis is a wholly-retraceable and thus logically defensible, answer, not a partially retraceable "good enough" judgment. Analytically-derived answers are neither the result of a compromise between vicarious functioning cues, nor a compromise between competing organizing principles; answers are produced by one principle which dominates all others. Compromise is not merely resisted by analytical cognition, it is anathema to it, for compromise is capitualtion; compromise renders an otherwise wholly consistent organizing principle internally inconsistent. As indicated above, mutual substitutability at the central region occurs only insofar as the organizing principles are part of a tautological system. Ideologically-derived analytical organizing principles, however, lead to dispute precisely because they are not mutually substitutable with other ideologically-derived principles; indeed, the dispute is based on grounds of their incompatibility. Thus, the mathematician's way of conflict management differs from that of the ideologue. The former seeks tautologies, systems of analysis that permit incorporation of, and thus reconciliation of, competing theories, as well as the explicit identification of the congruence between theories. The latter, on the other hand, seeks capitulation; the dispute is pursued until capitulation occurs, or until outside forces demand the return of quasi-rationality (and thus the abondonment of consistency and the acceptance of compromise). (See Tversky & Kahneman, 1981, p. 458, for a recent suggestion that internal consistency be abandoned as a criterion of rationality in favor of "the predictive criterion of rationality.")

Conflict in science. Compromise is not permitted within scientific work for different reasons; the fact that science is based on the use of analytical organizing principles means that there is no compromise, for example, between the wave and particle theory of light; there is a "complementarity principle," not a "compromise principle." The fact that analysis demands capitulation, not compromise, is at the basis of the "crucial experiment," so admired by analytical scientists and philosophers of science, admired because the crucial experiment demands a set of conditions that will discriminate with finality between two competing alternative organizing principles (theories) that will permit no compromise. And it is the falsification of at least one competing organizing principle in these specific conditions that marks an increase in analytical explanatory power and precision in empirical prediction.

Thus, scientific endeavor has the enormous advantage of being able to resort to controlled, empirical test for the falsification of theories. Regrettably, political, social and economic theories do not have this opportunity. As a result, methods proposed (and available) for resolving dispute threaten the existence of life on the only planet where it is apparent. All of the results of research on man's cognitive activity points to the need for a better way, for the development of cognitive support systems.

Cognitive Support Systems

Throughout the above presentation there runs a theme of reciprocity; as just indicated, the responsibility provided by analytical cognition is purchased at the increasing risk of the rejection of common sense. No one expresses this point better than the philosopher Pepper (1948; see also Hammond, et al., 1980, pp. 3-4):

> This tension between common sense and expert knowledge, between cognitive security without responsibility and cognitive responsibility without full security, is the interior

dynamics of the knowledge situation. The indefiniteness of much detail in common sense, its contradictions, its lack of established grounds, drive thought to seek definitiveness, consistency, and reasons. Thought finds these in the criticized and refined knowledge of mathematics, science, and philosophy, only to discover the these tend to thin out into arbitrary definitions, pointer readings, and tentative hypotheses. Astounded at the thinness and hollowness of these culminating achievements of conscientiously responsible cognition, thought seeks matter for its definitions, significance for its pointer readings, and support for its wobbling hypotheses. Responsible cognition finds itself insecure as a result of the very earnestness of its virtues. But where shall it turn? It does, in fact, turn back to common sense, that indefinite and irresponsible source which it so lately scorned. But it does so, generally, with a bad grace. After filling its empty definitions and pointer readings and hypotheses with meanings out of the rich confusion of common sense, it generally turns its head away, shuts its eyes to what it has been doing, and affirms dogmatically the self-evidence and certainty of the common-sense significance it has drawn into its concepts. Then it pretends to be securely based on self-evident principles or indubitable facts. If our . . . criticism of dogmatism is correct, however, this security in self-evidence and indubitability has proved questionable. And critical knowledge hangs over a vacuum unless it acknowledges openly the actual, though strange, source of its significance and security in the uncriticized material of common sense. Thus the circle is completed. Common sense continually demands the responsible criticism of refined knowledge, and refined knowledge sooner or later requires the security of common-sense support.

Why cannot the two merge? No doubt, that is the inherent aim of cognition. (pp. 3-4)

No doubt, then, one of the aims of cognitive support systems should be to make it possible for the security of common sense to merge with the responsibility of analysis in a manner that incorporates the assets of both, and reduces the liabilities of both.

Placed in the present theoretical context, Pepper's description of the reciprocity between intuition and analysis thus provides a clear directive for the development of cognitive support systems: Make it possible for the full capacity of cognition to be brought to bear on the full range of cognitive tasks. In order for that to be accomplished, a unified theory of cognition that incorporates all of our knowledge will be required if we are to develop support systems that will enhance our cognitive abilities, and thus enhance the likelihood of obtaining intelligent solutions to those many cognitive problems that currently seem to baffle us.

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TABLE 1

COMPLEXITY OF TASK STRUCTURE

INDUCING INTUITION	INDUCING ANALYSIS
1. TEXTURE OF JUDGMENT SCALE	1. TEXTURE OF JUDGMENT SCALE
A. MANY ALTERNATIVES	A. FEW ALTERNATIVES
B. MANY STEPS TO SOLUTION	B. FEW STEPS
2. NUMBER OF CUES PRESENTED	2. NUMBER OF CUES PRESENTED
A. MANY (>5) CUES CONTEMPORANEOUSLY DISPLAYED	A. FEW (2-4) CUES SEQUENTIALLY ENCOUNTERED
3. VICARIOUS MEDIATION	3. VICARIOUS MEDIATION
A. INTRA-ECOLOGICAL CORRELATIONS PRESENT TO LARGE (R = .5) DEGREE (HORIZONTALLY)	A. INTRA-ECOLOGICAL CORRELATIONS MINIMAL (VERTICALLY)
4. CUE DISTRIBUTION CHARACTERISTICS	4. CUE DISTRIBUTION CHARACTERISTICS
A. NORMAL	A. PEAKED
B. LINEAR FUNCTION FORMS	B. NONLINEAR, NONMONOTONIC FUNCTION FORMS
5. WEIGHTS	5. WEIGHTS
A. EQUAL	A. UNEQUAL
6. ORGANIZING PRINCIPLE	6. ORGANIZING PRINCIPLE
A. LINEAR MODEL	A. NONLINEAR MODEL

TABLE 1 (CONTINUED)

AMBIGUITY OF TASK CONTENT

INDUCING INTUITION	INDUCING ANALYSIS
1. AVAILABILITY OF AN ORGANIZING PRINCIPLE	1. AVAILABILITY OF AN ORGANIZING PRINCIPLE
A. NOT AVAILABLE	A. READILY AVAILABLE
2. TASK OUTCOME AVAILABLE	2. TASK OUTCOME AVAILABLE
A. NOT AVAILABLE	A. READILY AVAILABLE
3. FAMILIARITY WITH CONTENT	3. FAMILIARITY WITH CONTENT
A. NOT FAMILIAR	A. HIGHLY FAMILIAR
4. FEEDFORWARD	4. FEEDFORWARD
A. NO TRAINING, NO INFORMATION	A. PRIOR SKILL, INFORMATION
5. FEEDBACK	5. FEEDBACK
A. MINIMAL	A. COGNITIVE FEEDBACK

FORM OF TASK PRESENTATION

INDUCING INTUITION	INDUCING ANALYSIS
1. TASK DECOMPOSITION	1. TASK DECOMPOSITION
A. A FOSTERIORI	A. A PRIORI
2. COGNITIVE DECOMPOSITION	2. COGNITIVE DECOMPOSITION
A. A POSTERIORI	A. A PRIORI
3. TYPE OF CUE DATA	3. TYPE OF CUE DATA
A. CONTINUOUS	A. DICHOTOMOUS
4. TYPE OF CUE DEFINITION	4. TYPE OF CUE DEFINITION
A. PICTORIAL	A. QUANTITATIVE
B. SUBJECT MEASURES CUE LEVELS	B. OBJECTIVE MEASURES
5. RESPONSE TIME PERMITTED OR IMPLIED	5. RESPONSE TIME PERMITTED OR IMPLIED
A. BRIEF	A. OPEN

TABLE 2

PREDICTIONS OF COGNITIVE PROPERTIES IN SINGLE-SYSTEM CASE

INTUITIVE COGNITION	ANALYTICAL COGNITION
1. Low cognitive control	1. Opposite
2. Unconscious data processing, with regard to weights, function forms, organizing principles	2. Opposite
3. Vicarious functioning (includes shifting cue utilization)	3. Opposite
4. Rapid data processing	4. Opposite
5. Raw data or events stored in memory	5. Complex organizing principles stored in memory
6. Pictorial metaphors predominant; verbal, quantitative metaphors absent	6. Verbal, quantitative metaphors serve as organizing principles and hypotheses; pictorial metaphors absent (or appear only during intuitive phase of problem solving)
7. Right hemispheric activity predominant	7. Left hemispheric activity predominant
8. Stable policy means rigidity	8. Stable judgment subject to change with new information

TABLE 2A

LIST OF PREDICTIONS REGARDING PERFORMANCE IN SINGLE-SYSTEM CASE

1. INCONSISTENCY A. LOW PREDICTABILITY OF JUDGMENTS OVER TIME B. LOGICAL INCONSISTENCY (WHERE APPROPRIATE) C. FAILURE TO CONFORM TO MATH AXIOMS (WHERE APPROPRIATE)	1. OPPOSITE
2. LACK OF RETRACEABILITY OR AWARENESS OF PROCESS A. DIFFICULTY IN VERBALIZING B. EXPRESSING QUANTITATIVELY, COGNITIVE ACTIVITY	2. HIGH DEGREE OF RETRACEABILITY WHEN MOVING TOWARD SOLUTION; WHEN BLOCKED SUBJECT OFTEN RESORTS TO PICTORIAL REPRESENTATION OF THOUGHT, OR PICTORIAL ANALOGIES OR METAPHORS, THAT ARE RECOVERED
3. BRIEF RESPONSE TIME A. OTHER INDICATIONS OF ABSENCE OF ANALYSIS	3. OPPOSITE
4. LOW CONFIDENCE IN JUDGMENTS	4. OPPOSITE
5. CHANGE A. CHANGE IN COGNITIVE SYSTEM LIMITED TO CHANGE IN CUE WEIGHTS AS POLICY FORMED	5. CHANGE A. CHANGE IN WEIGHTS, FUNCTION FORMS AND ORGANIZING PRINCIPLES UNTIL STABLE POLICY REACHED B. RAPID CHANGE OCCURS WITH NEW INFORMATION
6. EQUAL WEIGHTING OF CUES OVER LONG TERM (I.E., "MATCHING" RATHER THAN "MAXIMIZING" BEHAVIOR)	6. OPPOSITE; WEIGHT CONCEPT NOT APPLICABLE
7. LINEAR FUNCTION FORMS	7. OPPOSITE
8. WEIGHTED AVERAGING ORGANIZING PRINCIPLE (COMPROMISE). NOTE: MATCHING HERE ALSO	8. ANY ORGANIZING PRINCIPLE (OTHER THAN WEIGHTED AVERAGING POSSIBLE)
9. EVENT MEMORY	9. MEMORY OF PRINCIPLES (INCLUDING METAPHORS IN CREATIVE PHASES)
10. RIGHT SIDE BRAIN ACTIVITY	10. OPPOSITE

TABLE 3

PREDICTIONS OF COGNITIVE PROPERTIES IN DOUBLE-SYSTEM CASE

INTUITIVE COGNITION	ANALYTICAL COGNITION
1. Low cognitive control	1. Opposite
2. Unconscious data processing with regard to weights, feedforward, organizing principles	2. Opposite
3. Vicarious functioning (includes shifting cue utilization)	3. Opposite
4. Rapid data processing	4. Opposite
5. Raw data or events stored in memory	5. Complex organizing principles stored in memory
6. Pictorial metaphors predominant; verbal, quantitative metaphors absent	6. Verbal, quantitative metaphors serve as organizing principles and hypotheses; pictorial metaphors absent (or appear only during intuitive phase of problem solving)
7. Right hemispheric activity predominant	7. Left hemispheric activity predominant
8. Stable policy means rigidity	8. Stable judgment subject to change with new information

TABLE 3A

PREDICTIONS OF ACHIEVEMENT FOR DOUBLE-SYSTEM CASE

(NOTE: PREDICTIONS OF PERFORMANCE FROM SINGLE-SYSTEM CASE CARRY FORWARD.)

INTUITIVE COGNITION	ANALYTICAL COGNITION
1. SLOW, 'STUPID' LEARNING FROM INEXACT (PROBABILISTIC) OUTCOMES; E.G., LARGE NUMBER OF TRIALS TO SOLUTION	1. OPPOSITE
2. NORMAL DISTRIBUTION OF TASK ERRORS	2. NON-NORMAL DISTRIBUTION OF ERRORS
3. 'STEREOTYPED,' PERSISTENT USE OF CUES	3. OPPOSITE
4. FREQUENT APPEAL TO EVENT MEMORY FOR RECALL OF TASK PROPERTIES AND PERFORMANCE	4. FREQUENT APPEAL TO ORGANIZING PRINCIPLE FOR RECALL OF TASK PROPERTIES AND PERFORMANCE
5. TRANSFER LOW; TASKS WITH DIFFERENT CONTENT	5. TRANSFER HIGH OVER DIFFERING CONTENT
6. UNDERCONFIDENCE (CONTRAST BETWEEN OBSERVED PERFORMANCE AND REPORT OF CONFIDENCE)	6. OPPOSITE
7. INCONSISTENCY MATCHES TASK UNPREDICTABILITY OVER OCCASIONS	7. INCONSISTENCY FROM TRIAL TO TRIAL; NOT MATCHED TO TASK; MAXIMIZING STRATEGY IN TASKS PROVEN TO BE STOCHASTIC

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